

# CSC 480: Artificial Intelligence

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# Course Overview

- ❖ **Introduction**
- ❖ **Intelligent Agents**
- ❖ **Search**
  - ❖ problem solving through search
  - ❖ uninformed search
  - ❖ informed search
  - ❖ local search and constraint satisfaction
- ❖ **Games**
  - ❖ games as search problems
- ❖ **Knowledge and Reasoning**
  - ❖ reasoning agents
  - ❖ propositional logic
  - ❖ predicate logic
  - ❖ planning
- ❖ knowledge-based systems
- ❖ uncertain knowledge and reasoning
- ❖ **Learning**
  - ❖ learning from observation
  - ❖ reinforcement learning
  - ❖ neural networks
- ❖ **Natural Language Processing**
- ❖ **Robotics**
- ❖ **Philosophical, Ethical, Social Issues with AI**
- ❖ **Conclusions**

# Chapter Overview

## Introduction

- ❖ Logistics
- ❖ Motivation
- ❖ Objectives
- ❖ What is Artificial Intelligence?
  - ❖ definitions
  - ❖ Turing test
  - ❖ cognitive modeling
  - ❖ rational thinking
  - ❖ acting rationally
- ❖ Foundations of Artificial Intelligence
  - ❖ philosophy
  - ❖ mathematics
  - ❖ psychology
  - ❖ computer science
- ❖ linguistics
- ❖ History of Artificial Intelligence
- ❖ Important Concepts and Terms
- ❖ Chapter Summary

# Instructor

- ❖ **Dr. Franz J. Kurfess**
- ❖ Professor, CSC Dept.
- ❖ **Areas of Interest**
  - ❖ Artificial Intelligence
  - ❖ Knowledge Management, Intelligent Agents
  - ❖ Neural Networks & Structured Knowledge
  - ❖ Human-Computer Interaction
  - ❖ User-Centered Design
- ❖ **Contact**
  - ❖ preferably via email: [fkurfess@calpoly.edu](mailto:fkurfess@calpoly.edu)
  - ❖ office hours:
    - ❖ Mon, Wed 2:30 - 4:00 pm
    - ❖ Tue, Thu 4:40 - 5:30 pm
  - ❖ Web page <http://www.csc.calpoly.edu/~fkurfess>
  - ❖ office 14-257

# Logistics

- ❖ **Enrollment Issues**
  - ❖ wait list, crashing class
  - ❖ to request consideration, fill out form at  
<http://goo.gl/forms/deRP63un3I>
- ❖ **Course Materials**
  - ❖ recommended textbooks
    - ❖ Russell & Norvig: Artificial Intelligence - A Modern Approach (AIMA)
    - ❖ Ertel: Introduction to Artificial Intelligence
  - ❖ handouts
    - ❖ lecture notes via Dropbox repository
  - ❖ course Web page <http://users.csc.calpoly.edu/~fkurfess/Courses/480/F15/>
- ❖ **PolyLearn**
  - ❖ used to record grades
  - ❖ may be used for some assignment submissions
- ❖ **Piazza**
  - ❖ possibly used as discussion forum

# Class Work

- ❖ **Lab and Homework Assignments**
  - ❖ Lab 1 due next Tue, end of the day
    - ❖ submission via Web form linked from the lab description on the class Web page
- ❖ **AI Nuggets**
  - ❖ first presentations
  - ❖ provide access on Google Docs or similar
- ❖ **Term Project**
  - ❖ topics and teams during lab time

# Logistics - Project

- ❖ **Team Project**
  - ❖ quarter-long
  - ❖ ~ five team members
  - ❖ collaboration with students from Munich University of Applied Sciences
- ❖ **Project Topics**
  - ❖ overall theme “Matching with Artificial Intelligence”
  - ❖ some proposed topics
  - ❖ students select their topic
    - ❖ subject to approval by the instructor
- ❖ **Related Work**
  - ❖ within this class
    - ❖ coordination between project, assignments and research paper is strongly encouraged
  - ❖ outside of class
    - ❖ Master’s thesis
    - ❖ senior project

# Logistics - CSC Lab Support

- ❖ CSC currently has no full-time sysadmins
- ❖ sysadmin work done by faculty, temporary personnel
  - ❖ Prof. Bellardo
- ❖ HCI lab assistant
  - ❖ Noah Dietz
  - ❖ checkout of devices
  - ❖ some support in use of devices

# Logistics - International Exchange Opportunities

- ❖ **Cal Poly Exchange Partners**
  - ❖ multiple universities in different corners of the world
  - ❖ some of them mostly for undergrads, but arrangements can be made for grad students
- ❖ **Strategic Partner: Munich University of Applied Sciences (MUAS)**
  - ❖ long-standing exchange program for undergrads expanded to grad programs and research collaboration
  - ❖ funding from the German Academic Exchange Service (Deutscher Akademischer Austauschdienst - DAAD)
    - ❖ ~ two MUAS and two Cal Poly grad students per year for 6 months
      - ❖ collaboration on Master's theses and research projects
    - ❖ also some funding for faculty visits

# Logistics - Digital Democracy Project

- ❖ see flyer at Dr. Khosmood's home page
  - ❖ <http://users.csc.calpoly.edu/~foaad/DDF15.pdf>
- ❖ opportunities for
  - ❖ class projects
  - ❖ Master's theses
  - ❖ senior projects
  - ❖ paid project work

# Logistics - Research Projects

- ❖ **Facial Gesture Recognition**
  - ❖ sponsored by Intel
  - ❖ ideally in combination with a Master's thesis
- ❖ **Interaction Spaces & Interaction Modeling**
  - ❖ Master's thesis or senior project
  - ❖ some funding available

# Course Material

- ❖ **on the Web (<http://www.csc.calpoly.edu/~fkurfess>)**
  - ❖ syllabus
  - ❖ schedule
  - ❖ student presentation schedule
  - ❖ project information
  - ❖ homework and lab assignment descriptions
  - ❖ most lab assignment submissions
- ❖ **Administration**
  - ❖ PolyLearn/Moodle
  - ❖ grades
  - ❖ assignment and some lab submissions
- ❖ **Discussion boards**
  - ❖ Piazza
- ❖ **Project Repositories**
  - ❖ source code
    - ❖ github
  - ❖ project documentation
    - ❖ Google Docs
    - ❖ Dropbox



# Term Project

- ❖ **development of a practical application in a team**
  - ❖ prototype, emphasis on conceptual and design issues, not so much performance
- ❖ **implementation must be accessible to others**
  - ❖ e.g. Web/Java
- ❖ **milestones/deliverables**
- ❖ **mid-quarter and final presentation/display**
- ❖ **peer evaluation**
  - ❖ each team evaluates the system of another team
- ❖ **information exchange on the Web**
  - ❖ course Web site
  - ❖ project repository

# Homework and Lab Assignments

- ❖ individual assignments
- ❖ some lab exercises in small teams
  - ❖ documentation, hand-ins usually per person
- ❖ may consist of questions, exercises, outlines, programs, experiments

# Exams

- ❖ **weekly quizzes**
  - ❖ typically 10 questions
  - ❖ most of them multiple choice
- ❖ **score improvement opportunities**
  - ❖ makeup questions ??
  - ❖ best 10 out of 15 or 16 quizzes ??
- ❖ **no midterm or final exams**

# Motivation

- ❖ **scientific curiosity**
  - ❖ try to understand entities that exhibit intelligence
- ❖ **engineering challenges**
  - ❖ building systems that exhibit intelligence
- ❖ **some tasks that seem to require intelligence can be solved by computers**
- ❖ **progress in computer performance and computational methods enables the solution of complex problems by computers**
- ❖ **humans may be relieved from tedious tasks**

# Objectives

- ❖ become familiar with criteria that distinguish human from artificial intelligence
- ❖ know about different approaches to analyze intelligent behavior
- ❖ understand the influence of other fields on artificial intelligence
- ❖ be familiar with the important historical phases the field of artificial intelligence went through

# Exercise: Intelligent Systems

- ❖ **select a task that you believe requires intelligence**
  - ❖ examples: playing chess, solving puzzles, translating from English to German, finding a proof for a theorem
- ❖ **for that task, sketch a computer-based system that tries to solve the task**
  - ❖ architecture, components, behavior
- ❖ **what are the computational methods your system relies on**
  - ❖ e.g. data bases, hash tables, matrix multiplication, graph traversal, linked lists,
- ❖ **what are the main challenges**
- ❖ **how do humans tackle the task**

# Trying to define AI

- ❖ so far, there is no generally accepted definition of Artificial Intelligence
  - ❖ textbooks either skirt the issue, or emphasize particular aspects
    - ❖ frequently based on the specific interests or viewpoints of the authors
  - ❖ not uncommon in relatively young fields
    - ❖ is there a commonly accepted definition of “Computer Science”
      - ❖ is it a ‘hard’ or ‘soft’ science (or neither)

# Statistics, Machine Learning, Data Mining and AI

- ❖ Lab 10 Submission: AI and Humor -> Ohh the differences ....
  - ❖ by Austin Dworaczyk Wiltshire - Tuesday, November 27, 2012, 3:10 PM

"What is the difference between statistics, machine learning, AI and data mining?

If there are up to 3 variables, it is statistics.

If the problem is NP-complete, it is machine learning.

If the problem is PSPACE- complete, it is AI.

If you don't know what is PSPACE-complete, it is data mining."

<https://www.facebook.com/alangsmello/posts/4832538494908>

# PSPACE-complete Decision Problem

- ❖ computational complexity theory
- ❖ can be solved using an amount of memory that is polynomial in the input length (polynomial space), and
- ❖ every other problem that can be solved in polynomial space can be transformed to it in polynomial time.
- ❖ PSPACE-complete problems can be thought of as the hardest problems in PSPACE
  - ❖ a solution to any one such problem could easily be used to solve any other problem in PSPACE
- ❖ PSPACE-complete problems are widely suspected to be outside of the more famous complexity classes P and NP
  - ❖ that is not known.
  - ❖ it is known that they lie outside of the class NC (a class of problems with highly efficient parallel algorithms),
    - ❖ problems in NC can be solved in an amount of space polynomial in the logarithm of the input size, and
    - ❖ the class of problems solvable in such a small amount of space is strictly contained in PSPACE by the space hierarchy theorem

<http://en.wikipedia.org/wiki/PSPACE-complete>

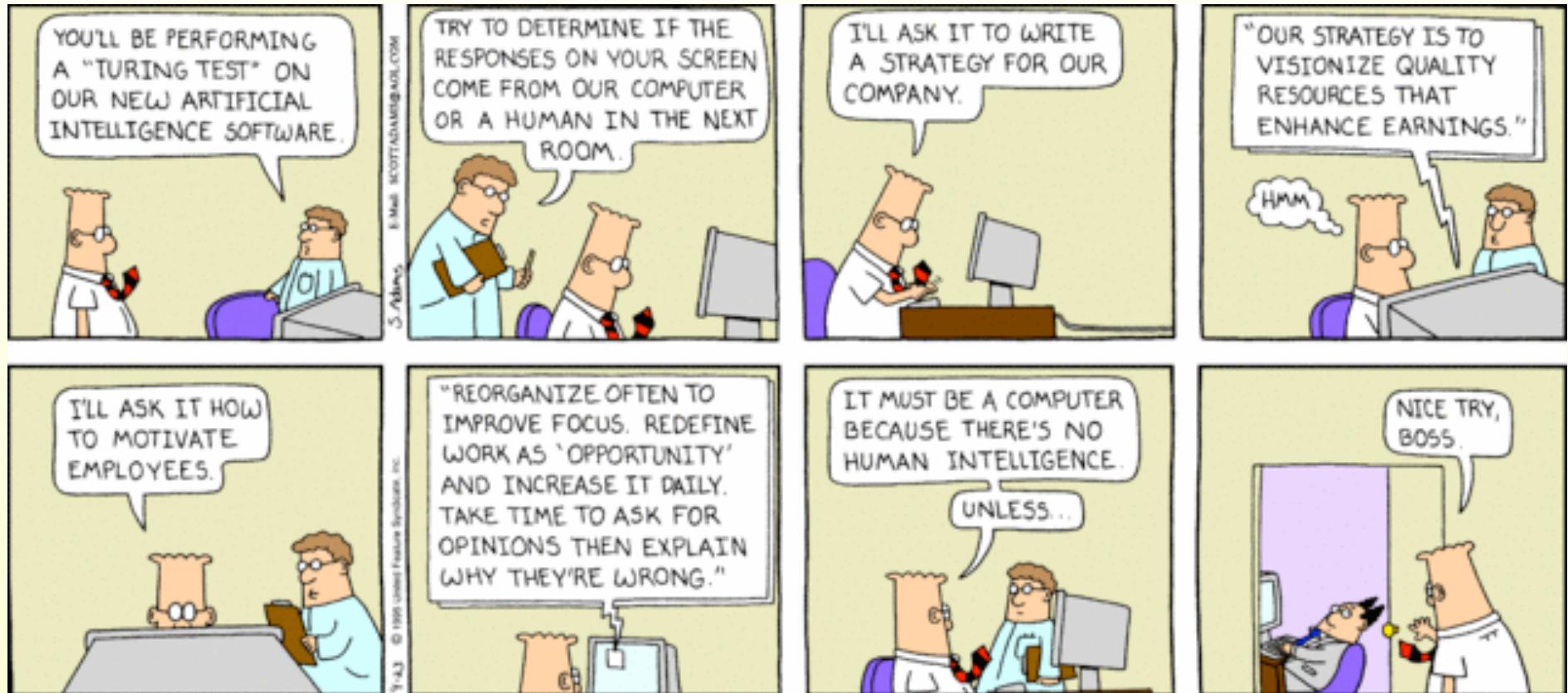
© Franz J. Kurfess



# Examples PSPACE-complete Decision Problems

- ❖ **Regular expressions**
  - ❖ Given a regular expression R, determining whether it generates every string over its alphabet is PSPACE-complete.
- ❖ **Context-sensitive grammars**
  - ❖ The first known PSPACE-complete problem was the word problem for deterministic context-sensitive grammars.
- ❖ **Quantified Boolean formulas (QBF)**
  - ❖ a generalization of the first known NP-complete problem, the Boolean satisfiability problem (SAT)
    - ❖ SAT is the problem of whether there are assignments of truth values to variables that make a Boolean expression true
    - ❖ in QBF both universally and existentially quantified variables are allowed
- ❖ **Games and Puzzles**
  - ❖ many puzzles are NP-complete
  - ❖ many games are PSPACE-complete
    - ❖ may have to be generalized, eg. by using a  $n \times n$  board
    - ❖ may have to be placed under a polynomial bound for the number of moves

# Dilbert's Turing Test



<http://dilbert.com/strips/comic/1995-04-23/>

# Examples of Definitions

## ❖ cognitive approaches

- ❖ emphasis on the way systems work or “think”
- ❖ requires insight into the internal representations and processes of the system

## ❖ behavioral approaches

- ❖ only activities observed from the outside are taken into account

## ❖ human-like systems

- ❖ try to emulate human intelligence

## ❖ rational systems

- ❖ systems that do the “right thing”
- ❖ idealized concept of intelligence

# Systems That Think Like Humans

- ❖ “The exciting new effort to make computers think ... machines with minds, in the full and literal sense”  
[Haugeland, 1985]
- ❖ “[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning ...”  
[Bellman, 1978]

# Systems That Act Like Humans

- ❖ “The art of creating machines that perform functions that require intelligence when performed by people”  
[Kurzweil, 1990]
- ❖ “The study of how to make computers do things at which, at the moment, people are better”  
[Rich and Knight, 1991]

# Systems That Think Rationally

- ❖ “The study of mental faculties through the use of computational models”  
[Charniak and McDermott, 1985]
- ❖ “The study of the computations that make it possible to perceive, reason, and act”  
[Winston, 1992]

# Systems That Act Rationally

- ❖ “A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes”  
[Schalkhoff, 1990]
- ❖ “The branch of computer science that is concerned with the automation of intelligent behavior”  
[Luger and Stubblefield, 1993]

# The Turing Test

- ❖ proposed by Alan Turing in 1950 to provide an operational definition of intelligent behavior
  - ❖ the ability to achieve human-level performance to fool an interrogator
- ❖ the computer is interrogated by a human
- ❖ it passes the test if the interrogator cannot tell the computer or human



Movie poster for The Imitation Game

# Basic Capabilities

for passing the Turing test

- ❖ **natural language processing**
  - ❖ communicate with the interrogator
- ❖ **knowledge representation**
  - ❖ store information
- ❖ **automated reasoning**
  - ❖ answer questions, draw conclusions
- ❖ **machine learning**
  - ❖ adapt behavior
  - ❖ detect patterns

# Relevance of the Turing Test

- ❖ not much concentrated effort has been spent on building computers that pass the test
- ❖ Loebner Prize
  - ❖ there is a competition and a prize for a somewhat revised challenge
  - ❖ see details at  
<http://www.loebner.net/Prizef/loebner-prize.html>
- ❖ “Total Turing Test”
  - ❖ includes video interface and a “hatch” for physical objects
  - ❖ requires computer vision and robotics as additional capabilities

# Turing Test Extra Credit

- ❖ Lab 10 Submission: AI and Humor -> XKCD
  - ❖ by Brian Gomberg - Tuesday, November 27

TURING TEST EXTRA CREDIT:  
CONVINCE THE EXAMINER  
THAT HE'S A COMPUTER.

YOU KNOW, YOU MAKE  
SOME REALLY GOOD POINTS.

I  
I'M ... NOT EVEN SURE  
WHO I AM ANYMORE.



[http://imgs.xkcd.com/comics/turing\\_test.png](http://imgs.xkcd.com/comics/turing_test.png)

# Cognitive Modeling

- ❖ tries to construct theories of how the human mind works
- ❖ uses computer models from AI and experimental techniques from psychology
- ❖ most AI approaches are not directly based on cognitive models
  - ❖ often difficult to translate into computer programs
  - ❖ performance problems

# Rational Thinking

- ❖ **based on abstract “laws of thought”**
  - ❖ usually with mathematical logic as tool
- ❖ **problems and knowledge must be translated into formal descriptions**
- ❖ **the system uses an abstract reasoning mechanism to derive a solution**
- ❖ **serious real-world problems may be substantially different from their abstract counterparts**
  - ❖ difference between “in principle” and “in practice”

# Rational Agents

- ❖ **an agent that does “the right thing”**
  - ❖ it achieves its goals according to what it knows
  - ❖ perceives information from the environment
  - ❖ may utilize knowledge and reasoning to select actions
  - ❖ performs actions that may change the environment

# Behavioral Agents

- ❖ **an agent that exhibits some behavior required to perform a certain task**
  - ❖ the internal processes are largely irrelevant
  - ❖ may simply map inputs (“percepts”) onto actions
  - ❖ simple behaviors may be assembled into more complex ones

# Foundations of Artificial Intelligence

- ❖ philosophy
- ❖ mathematics
- ❖ psychology
- ❖ computer science
- ❖ linguistics

# Philosophy

- ❖ related questions have been asked by Greek philosophers like Plato, Socrates, Aristotle
- ❖ theories of language, reasoning, learning, the mind
- ❖ dualism (Descartes)
  - ❖ a part of the mind is outside of the material world
- ❖ materialism (Leibniz)
  - ❖ all the world operates according to the laws of physics

# Mathematics

- ❖ **formalization of tasks and problems**
- ❖ **logic**
  - ❖ propositional logic
  - ❖ predicate logic
- ❖ **computation**
  - ❖ Church-Turing thesis
  - ❖ intractability: NP-complete problems
- ❖ **probability**
  - ❖ degree of certainty/belief

# Psychology

- ❖ **behaviorism**

- ❖ only observable and measurable percepts and responses are considered
  - ❖ mental constructs are considered as unscientific
    - ❖ knowledge, beliefs, goals, reasoning steps

- ❖ **cognitive psychology**

- ❖ the brain stores and processes information
  - ❖ cognitive processes describe internal activities of the brain

# Computer Science

- ❖ provides tools for testing theories
- ❖ programmability
- ❖ speed
- ❖ storage
- ❖ actions

# Linguistics

- ❖ **understanding and analysis of language**
  - ❖ sentence structure, subject matter, context
- ❖ **knowledge representation**
- ❖ **computational linguistics, natural language processing**
  - ❖ hybrid field combining AI and linguistics

# AI through the ages

# AI Timeline: 1950 - 1973

After ambitious beginnings, the discipline of artificial intelligence quickly split into several interrelated subfields

1950

Alan Turing proposes that a digital computer could be programmed to answer questions as accurately as a human can

1958

Allen Newell and Herbert Simon predict that "within 10 years a digital computer will be the world's chess champion". It actually takes 40

1965

The first chatbot, a psychotherapy program called ELIZA, carries on rudimentary conversations

1956

The term "artificial intelligence" is coined at Dartmouth University by the creators of the nascent field

1961

Computer program solves calculus problems at the first-year university level

1973

Freddy Robot uses visual perception to locate and assemble models

1967

The STUDENT program solves high-school-level algebra problem, written in words

Roots of AI

Representation and reasoning

Understanding natural language

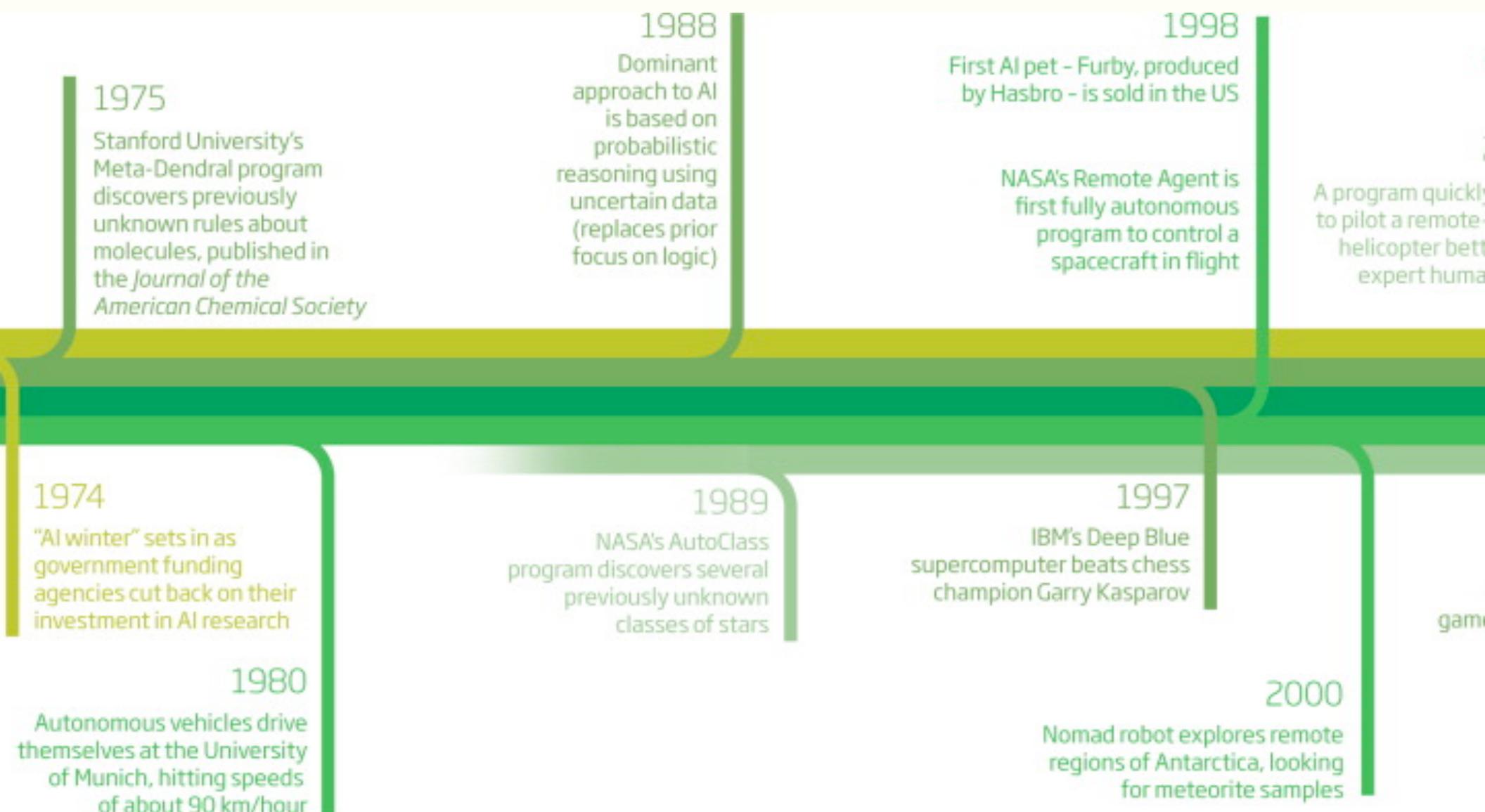
Robotics

Machine learning

Peter Norvig, Artificial intelligence: Early ambitions, *New Scientist*, Volume 216, Issue 2889, 3 November 2012, Pages ii-iii, ISSN 0262-4079, 10.1016/S0262-4079(12)62783-3.  
(<http://www.sciencedirect.com/science/article/pii/S0262407912627833>)

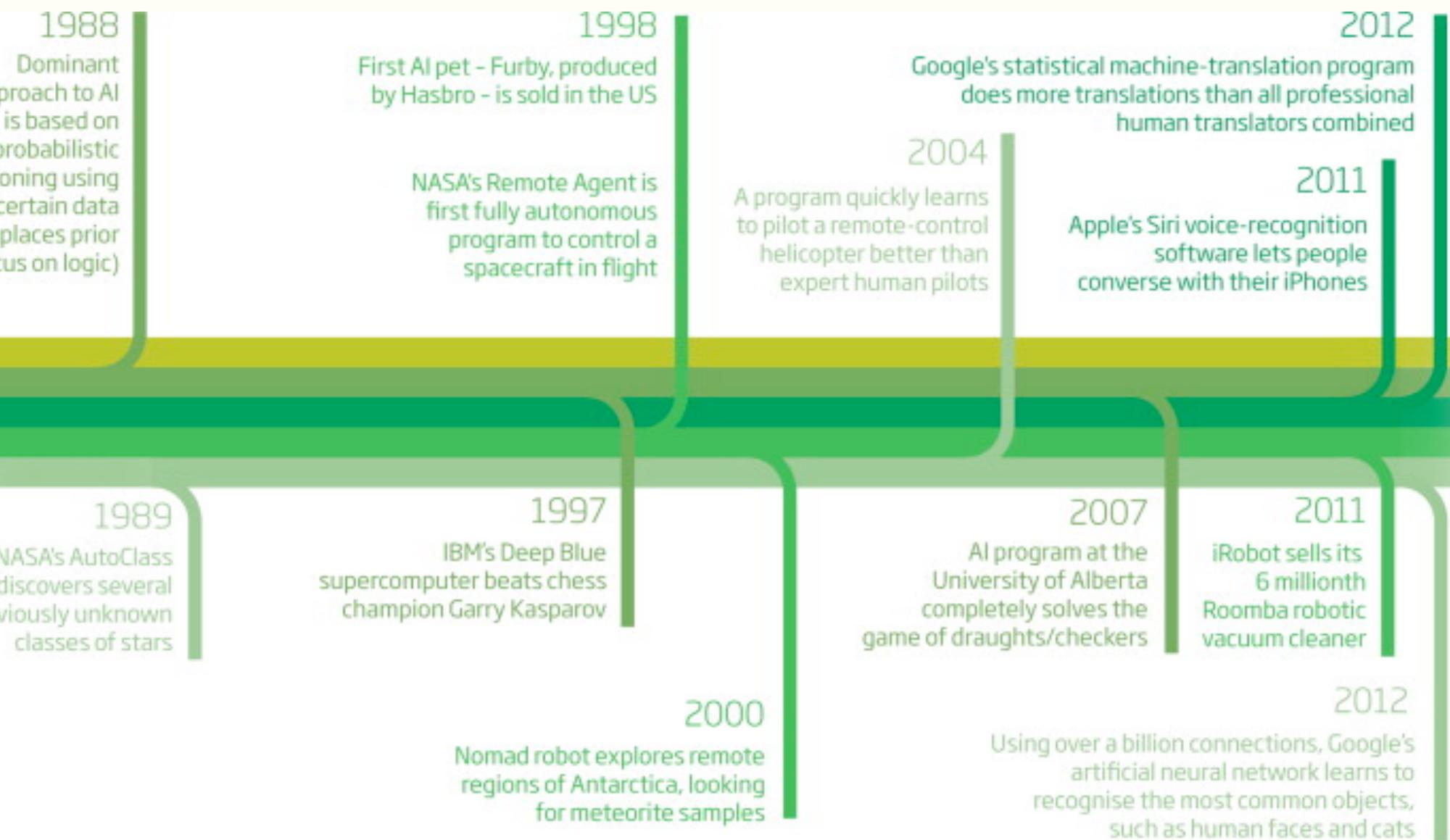


# AI Timeline: 1974 - 2000



Peter Norvig, Artificial intelligence: Early ambitions, *New Scientist*, Volume 216, Issue 2889, 3 November 2012, Pages ii-iii, ISSN 0262-4079, 10.1016/S0262-4079(12)62783-3.  
(<http://www.sciencedirect.com/science/article/pii/S0262407912627833>)

# AI Timeline: 2000 - 2012



Peter Norvig, Artificial intelligence: Early ambitions, New Scientist, Volume 216, Issue 2889, 3 November 2012, Pages ii-iii, ISSN 0262-4079, 10.1016/S0262-4079(12)62783-3.  
(<http://www.sciencedirect.com/science/article/pii/S0262407912627833>)

# Conception (late 40s, early 50s)

- ❖ artificial neurons (McCulloch and Pitts, 1943)
- ❖ learning in neurons (Hebb, 1949)
- ❖ chess programs (Shannon, 1950; Turing, 1953)
- ❖ neural computer (Minsky and Edmonds, 1951)

# Birth: Summer 1956

- ❖ gathering of a group of scientists with an interest in computers and intelligence during a two-month workshop in Dartmouth, NH
- ❖ “naming” of the field by John McCarthy
- ❖ many of the participants became influential people in the field of AI

# Baby steps (late 1950s)

- ❖ **demonstration of programs solving simple problems that require some intelligence**
  - ❖ Logic Theorist (Newell and Simon, 1957)
  - ❖ checkers programs (Samuel, starting 1952)
- ❖ **development of some basic concepts and methods**
  - ❖ Lisp (McCarthy, 1958)
  - ❖ formal methods for knowledge representation and reasoning
- ❖ **mainly of interest to the small circle of relatives**

# Kindergarten (early 1960s)

- ❖ **child prodigies astound the world with their skills**
  - ❖ General Problem Solver (Newell and Simon, 1961)
  - ❖ Shakey the robot (SRI)
  - ❖ geometric analogies (Evans, 1968)
  - ❖ algebraic problems (Bobrow, 1967)
  - ❖ blocks world (Winston, 1970; Huffman, 1971; Fahlman, 1974; Waltz, 1975)
  - ❖ neural networks (Widrow and Hoff, 1960; Rosenblatt, 1962; Winograd and Cowan, 1963)
  - ❖ machine evolution/genetic algorithms (Friedberg, 1958)

# Teenage years (late 60s, early 70s)

- ❖ sometimes also referred to as “AI winter”
  
- ❖ microworlds aren’t the real thing: scalability and intractability problems
- ❖ neural networks can learn, but not very much (Minsky and Papert, 1969)
- ❖ expert systems are used in some real-life domains
- ❖ knowledge representation schemes become useful

# AI gets a job (early 80s)

- ❖ **commercial applications of AI systems**
  - ❖ R1 expert system for configuration of DEC computer systems (1981)
- ❖ **expert system shells**
- ❖ **AI machines and tools**

# Some skills get a boost (late 80s)

- ❖ after all, neural networks can learn more --  
in multiple layers (Rumelhart and McClelland, 1986)
- ❖ hidden Markov models help with speech problems
- ❖ planning becomes more systematic (Chapman, 1987)
- ❖ belief networks probably take some uncertainty out of reasoning (Pearl,  
1988)

# AI matures (90s)

- ❖ handwriting and speech recognition work -- more or less
- ❖ AI is in the driver's seat (Pomerleau, 1993)
  - ❖ but not allowed on regular roads
- ❖ wizards and assistants make easy tasks more difficult
- ❖ intelligent agents do not proliferate as successfully as viruses and spam

# Intelligent Agents appear (mid-90s)

- ❖ distinction between hardware emphasis (robots) and software emphasis (softbots)
- ❖ agent architectures
  - ❖ SOAR
- ❖ situated agents
  - ❖ embedded in real environments with continuous inputs
- ❖ Web-based agents
- ❖ the agent-oriented perspective helps tie together various subfields of AI
- ❖ but: “agents” has become a buzzword
  - ❖ widely (ab)used, often indiscriminately

# AI Vanishes (~2000)

- ❖ more and more AI approaches are incorporated into generic computing approaches
  - ❖ planning, scheduling
  - ❖ machine learning
  - ❖ natural language processing
  - ❖ reasoning
  - ❖ autonomy
- ❖ or subsumed under the latest buzzwords
  - ❖ Semantic Web
  - ❖ big data
  - ❖ smart <some computer-related term here>

# A Lack of Meaning (~ 2005)

- ❖ most AI methods are based on symbol manipulation and statistics
  - ❖ e.g. search engines
- ❖ the *interpretation* of generated statements is problematic
  - ❖ often left to humans
- ❖ the Semantic Web suggests to augment documents with metadata that describe their contents
  - ❖ computers still don't "understand", but they can perform tasks more competently

# AI Searches for Meaning (~2012)

- ❖ statistical methods are augmented with knowledge-centric methods
  - ❖ e.g., Google's Knowledge Graphs
- ❖ computers still can't "understand", but they consider content-based relations

# Outlook

## ❖ concepts and methods

- ❖ many are sound, and usable in practice
- ❖ some gaps still exist: “neat” vs. “scruffy” debate

## ❖ computational aspects

- ❖ most methods need improvement for wide-spread usage
- ❖ vastly improved computational resources (speed, storage space)

## ❖ applications

- ❖ reasonable number of applications in the real world
- ❖ many are “behind the scene”
- ❖ expansion to new domains

## ❖ education

- ❖ established practitioners may not know about new ways
- ❖ newcomers may repeat fruitless efforts from the past

# Important Concepts and Terms

- ❖ agent
- ❖ automated reasoning
- ❖ cognitive science
- ❖ computer science
- ❖ intelligence
- ❖ intelligent agent
- ❖ knowledge representation
- ❖ linguistics
- ❖ Lisp
- ❖ logic
- ❖ machine learning
- ❖ microworlds
- ❖ natural language processing
- ❖ neural network
- ❖ predicate logic
- ❖ propositional logic
- ❖ rational agent
- ❖ rationality
- ❖ Turing test

# Chapter Summary

- ❖ introduction to important concepts and terms
- ❖ relevance of Artificial Intelligence
- ❖ influence from other fields
- ❖ historical development of the field of Artificial Intelligence



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